A Study on the Self Adhesion of Carbon Fiber Prepreg and Dental Acrylic Resin on the Hybrid Composites of Thin Plate

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In this paper we describe an experimental study, this articles is to report, making by coalescence in the course of reaction hardening process of hybrid composite of carbon fiber (C.F.) prepreg not hardened yet and polymethyl methacrylate (P.M.M.A.) of not polymerized yet was experimented, thence coalesced hybrid composite was subjected to bending test to check in comparison with material of adhered construction and simple plates of C.F. and P.M.M.A..

As a result of this series of tests and experiments, it was found that. Self-adhered hybrid materials showed very excellent bending characteristics as in the case of adhered materials.

1. INTRODUCTION

It was reported in the previous articles that the hybrid composite in the form of sandwich or canapé construction of C.F. prepreg and acrylic resin had excellent bending rigidity and bending strength compared with resin base of P.M.M.A. simple substance and had rigidity of 16 times as much of rigidity of P.M.M.A. simple plate.[1),2)] It was also reported that hybrid thin plate composite of C.F. and P.M.M.A. in the range of 0.9mm could be easily made and that even thin plate in such thickness had rigidity of 16 times as much of that of P.M.M.A. simple plate.[1),2)] Such hybrid composite was made of C.F. plate and P.M.M.A. plate adhered to each other by epoxy resin. In this article, making by coalescence in the course of reaction hardening process of hybrid composite of C.F. prepreg not hardened yet and P.M.M.A. of not polymerized yet was experimented, thence coalesced hybrid composite was subjected to bending test to check in comparison with material of adhered construction and simple

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plates of C.F. and P.M.M.A..[4)~10)]

2. EXPERIMENTAL PROCEDURES

Hybrid composite of sandwich construction of about 1mm in total thickness having C.F.[3)] layers of 0.15 and 0.36mm on both sides and P.M.M.A. layer as core was made by self-adhesion. Namely, hybrid plates made by self-adhesion by combination of C.F. prepreg - P.M.M.A. preform, C.F. prepreg - P.M.M.A. plate and C.F. plate - P.M.M.A. preform, C.F. simple plate, P.M.M.A. simple plate, and C.F. plate -

Table 1 General properties of carbon fiber reinforced prepreg.

Tensile strength (kg/mm^2), fiber direction	140
Tensile elastic modulus (ton/mm^2), fiber direction	13
Bending strength (kg/mm^2), fiber direction	140
Bending elastic modulus (ton/mm^2), fiber direction	13
Compressive strength (kg/mm^2), fiber direction	100
Compressive elastic modulus (ton/mm^2), fiber direction	13
Poisson's ratio	0.3
Interlaminar shearing strength (kg/mm^2)	8
Izod impact value (kg·cm/cm·notch)	110
Bending creep (80% load of average strength), fiber direction	below 10% of static strain for 500 hr
Bending creep fracture strength (for 500 hr), fiber direction	above 80% of static strength
Tensile fatigue strength (10^7cycles)	above 60 kg/mm^2
Rockwell hardness (E scale)	90
Barcol hardness	70
Coefficient of friction (parallel to fiber)	0.25
PV value ($kg/cm^2 \cdot m/min$)	1000
Steady abrasion modulus (PV=500) ($mg/hr \cdot cm^2$)	2
Heat conductivity (Kcal/m/h/°c), fiber direction	4
Heat conductivity (Kcal/m/h/°c), normal to fiber	0.40
Coefficient of linear expansion (/°c), fiber direction	-1×10^{-7}
Coefficient of linear expansion (/°c), normal to fiber	35×10^{-6}
Specific heat (cal/g/°c)	0.16
Specific resistance of volume (Ω·cm), fiber direction	0.005
Specific resistance of volume (Ω·cm), normal to fiber	5.7

Carbon fiber content ratio: 60%vol (after hardening)
Condition of hardening : 170 °c 1 hr, post cure 170 °c 2 hr

P.M.M.A. plate (adhered) were bend-tested to find deflection and bending stress, as well as deflection and maximum stress on outside. Table 1 shows general properties of carbon fiber reinforced prepreg used for these experiments, and Table 2-3 show the dimensions of speciments of sandwich construction used for these experiments. C.F. plate was

Table 2 Dimension of specimen on the sandwich structure of both sides 0.15mm thickness carbon fiber.

Specimen		t_e (mm)	t_a (mm)	t_f (mm)	t (mm)	width,b (mm)
No.1:C.F.plate					0.99	10.14
No.2: C.F.prepreg	A	0.15	0.65	0.15	0.95	10.84
No.2: P.M.M.A.preform	B	0.15	0.60	0.15	0.90	10.65
No.3: C.F.prepreg	A	0.15	0.64	0.15	0.94	9.85
No.3: P.M.M.A.plate	B	0.15	0.63	0.15	0.93	12.00
No.4: C.F.plate	A	0.15	0.73	0.15	1.03	9.95
No.4: P.M.M.A.preform	B	0.15	0.70	0.15	1.00	10.28
No.5:Sandwich with adhesive		0.12	0.735	0.12	1.01	10.38
No.6:P.M.M.A.					0.91	10.00

where,

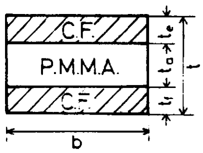

Table 3 Dimension of specimen on the sandwich structure of both sides 0.36mm thickness carbon fiber.

Specimen		t_e (mm)	t_a (mm)	t_f (mm)	t (mm)	width,b (mm)
No.1:C.F.plate					0.99	10.14
No.2: C.F.prepreg	A	0.36	0.37	0.36	1.09	10.39
No.2: P.M.M.A.preform	B	0.36	0.35	0.36	1.07	10.30
No.3: C.F.prepreg	A	0.35	0.35	0.35	1.05	10.51
No.3: P.M.M.A.plate	B	0.36	0.42	0.36	1.14	10.38
No.4: C.F.plate	A	0.37	0.30	0.37	1.04	10.84
No.4: P.M.M.A.preform	B	0.37	0.30	0.37	1.04	10.63
No.5:Sandwich with adhesive		0.30	0.33	0.30	0.95	10.19
No.6:P.M.M.A.					0.91	10.00

prepared by heating prepreg for 2-3 minutes in 150°c, pressure-hardening for 80 minutes at 150°c under 4kg/cm^2, cooling down outside of furnace, thence heating again for after-cure for 125 minutes in 170°c. Coalescence of C.F. prepreg and P.M.M.A. preform was carried out by putting tetron film of 1mm thick and tetron cloth on mold, onto which set were C.F. prepreg, P.M.M.A. not hardened yet and C.F. prepreg, thence hardening process as stated above was applied. P.M.M.A. plate was prepared by heating and pressurizing in 100°c for 40 minutes and under 100kg/cm^2 respectively after filling resin into mold, thence cooled down naturally. Coalescence process of C.F. plate with P.M.M.A. preform and C.F. prepreg with P.M.M.A. plate were carried out under molding conditions of P.M.M.A. plate and of C.F. plate respectively. Coalesced specimens were subjected to three-point bending test with span length of 50mm and load applied to the center.

3. EXPERIMENTAL RESULTS AND CONSIDERATION

Figs.1 and 2 show deflection, apparent stress and maximum stress on

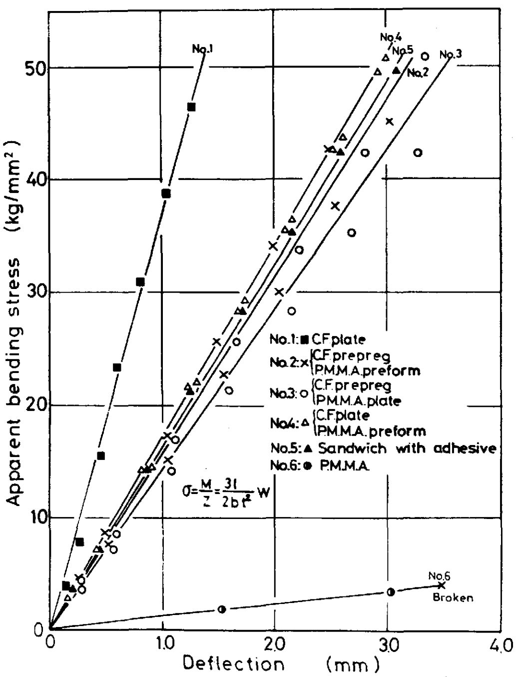

Fig.1 Relation between apparent bending stress and deflection on the sandwich structure of both sides 0.15mm thickness C.F..

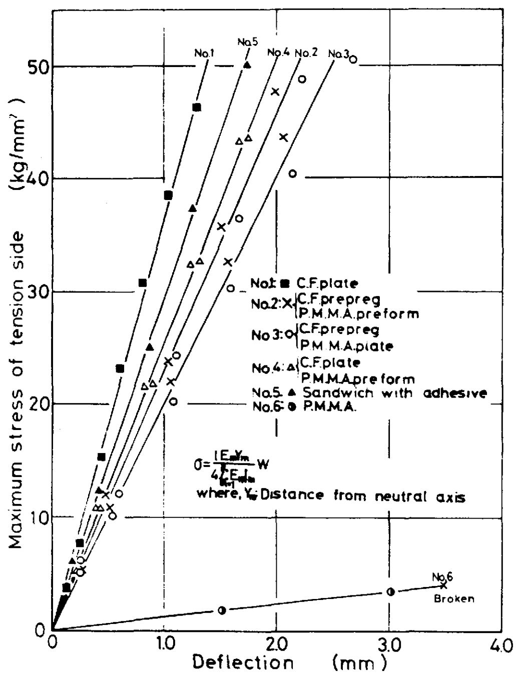

Fig.2 Relation between maximum stress of tension side and deflection on the sandwich structure of both sides 0.15mm thickness C.F..

tensile side observed under three-point bending with regard to specimens of sandwich construction having C.F. layers of 0.15mm thick on both sides. In comparison with P.M.M.A. plate, self-adhered hybrid composites and C.F. plate had bending rigidity of about 17 and about 39 times as much respectively, while maximum stress on outside under the same deflection of self-adhered hybrid composite and C.F. plate was about 24 and about 38 times respectively as much of maximum stress of P.M.M.A. plate. There were little differences among specimens by different self-adhesion or different adhesion methods, and any of the self-adhesion methods proved to be effective. Table 4 presents theoretical elastic modulus obtained by combination beam theory and apparent elastic modulus obtained through experiments, all with each hybrid

Table 4 Calculated and experimental apparent bending elastic modulus for the sandwich structure of both sides 0.15mm thickness carbon fiber.

Specimen			Calculated bending elastic modulus (kg/mm^2) *	Experimental bending elastic modulus (kg/mm^2)
No.1:C.F.plate			13000	15572
No.2:	C.F.prepreg P.M.M.A.preform	A	8823	6234
		B	9240	7559
No.3:	C.F.prepreg P.M.M.A.plate	A	9034	6471
		B	8962	5594
No.4:	C.F.plate P.M.M.A.preform	A	8834	6917
		B	8644	7125
No.5:Sandwich with adhesive			7355	6766
No.6:P.M.M.A.			300	289

* $\delta = \dfrac{\ell^3}{48 \sum_{m=1}^{n} E_m I_m} w$ ------ ① Deflection-load equation of sandwich beam.

$\delta = \dfrac{\ell^3}{48EI} w$ ------- ② Deflection-load equation of uniform section beam.

by ① and ②

$E = \dfrac{\sum_{m=1}^{n} E_m I_m}{I}$

where,

δ :Deflection.

ℓ :Span length (50mm).

w :Load.

E_m:Young's modulus for individual components.

P.M.M.A.: 300kg/mm²
C.F. : 13000kg/mm²

I_m:Secondary moment of area for individual components.

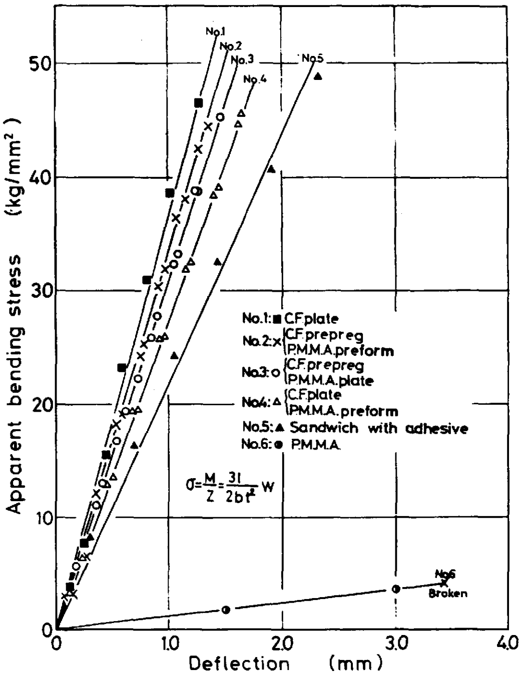

Fig.3 Relation between apparent bending stress and deflection on the sandwich structure of both sides 0.36mm thickness C.F..

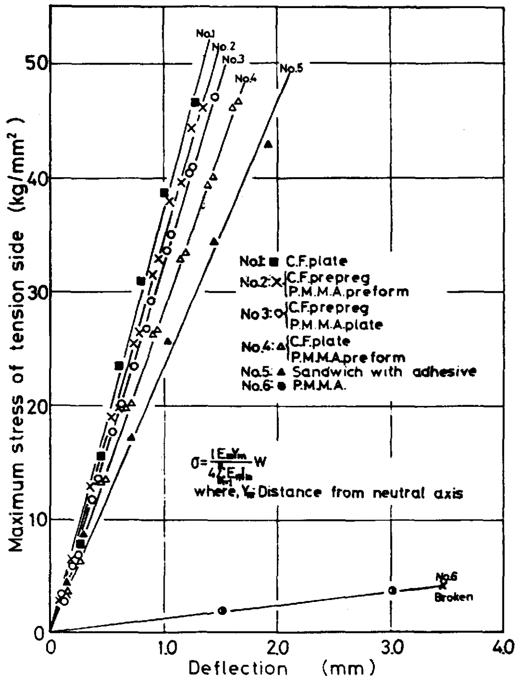

Fig.4 Relation between maximum stress of tension side and deflection on the sandwich structure of both sides 0.36mm thickness C.F..

Table 5 Calculated and experimental apparent bending elastic modulus for the sandwich structure of both sides 0.36mm thickness carbon fiber.

Specimen		Calculated bending elastic modulus (kg/mm²)	Experimental bending elastic modulus (kg/mm²)
No.1:C.F.plate		13000	15572
No.2: C.F.prepreg	A	12503	12997
No.2: P.M.M.A.preform	B	12556	13006
No.3: C.F.prepreg	A	12530	12599
No.3: P.M.M.A.plate	B	12365	11787
No.4: C.F.plate	A	12682	11458
No.4: P.M.M.A.preform	B	12683	11178
No.5:Sandwich with adhesive		12362	9649
No.6:P.M.M.A.		300	289

material. It was found that hybrid materials had 29-31 times as much in theoretical value and 22-26 times as much in experimental value of elastic modulus of P.M.M.A. plate. Figs.3 and 4 show results of three-point bending test conducted with specimen of sandwich construction having C.F. layers of 0.36mm on both sides. Self-adhered hybrid materials had 25 times as much of bending rigidity of P.M.M.A. plate and likewise about 25 times as much of maximum stress on outside under the same deflection of P.M.M.A. plate. Table 5 shows theoretical and experimental elastic moduli of combination beam, and it was known that the hybrid materials had 41-42 times in theoretical value and 39-45 times in experimental value as much of elastic modulus of P.M.M.A. plate.

4. CONCLUSION

The following summary can be made from the results of the present experiments. As a result of this series of tests and experiments, it was found that.

Self-adhered hybrid materials showed very excellent bending characteristics as in the case of adhered materials. Bending elastic modulus of self-adhered hybrid materials was about 30 times as much of that of P.M.M.A. plate. Sandwich construction having 0.36mm thick C.F. layers had better characteristics than adhered materials, and showed very similar bending elastic modulus of that of C.F. simple plate.

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